

HARO STRAIT TOMOGRAPHY EXPERIMENT, WHOI COMPONENT

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LONG-TERM GOALS

The goal of the Haro Strait Tomography Experiment was to develop and deploy an integrated ocean sampling network capable of simultaneous remote and in-situ measurements using multi-band acoustic tomography and autonomous underwater vehicles (AUVs), respectively. The project involved four groups: Woods Hole Oceanographic Institution was responsible for the tomography moorings and acoustic data acquisition; MIT Sea Grant operated the AUVs and processed the tomography data; University of Victoria operated a low-frequency tomography source; and Harvard University provided dynamic modeling. The integrated network was deployed in Haro Strait, British Columbia in summer 1996 to map a fast moving tidal front.

OBJECTIVES

The Haro Strait deployment was technologically demanding, requiring the simultaneous operation of several new and complex systems. The success of the 6 week deployment is indicated by the large and diverse data set obtained. The objective of the third and final funded year on the Haro Strait project was to collate, distribute and analyze this data set, and to report results through publications and presentations.

ACCOMPLISHMENTS

Due to an increase in scope of the Haro Strait deployment as compared to the original proposal (in particular, a substantial increase in the complexity of the moorings), a large part of the 1997 funding was used to cover cost overruns from the previous year. The remaining funding was used in three ways: (i) the production of a detailed data report; (ii) the development of a World-Wide-Web (WWW) page providing access to the experimental data; and (iii) analysis of the acoustic communications, array tracking, and sound pressure level (SPL) data recorded during the deployment.

A wide range of acoustic data was collected by the WHOI moorings at Haro Strait including mono- and bi-static tomography receptions in three different frequency bands, sea surface reflectometry data, hydrophone array tracking signals, acoustic communications signals from an AUV, and ambient sound spectra. As most of this data was gathered for the other groups involved in the experiment, it was important to provide full and timely documentation of the WHOI data set. The resulting data report was reviewed at the post-deployment meeting in

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Victoria, B.C. in December 1996 and the final version, including some preliminary data analysis results was made available in February of 1997.

Because of the number and geographic separation of the Haro Strait collaborators, it was decided at the December 1996 meeting to make the WHOI data set available via a specially-constructed WWW page. This page (accessible from www.telem.whoi.edu) provides general information on the experiment and some graphical results as well as access to a FTP data archive. The archive contains all of the data recorded during the experiment as well as the program listings and format conversion tools required to use the data. Experience has shown us that the WWW page provides a convenient, low-cost, and stable way of sharing this large data base.

Analysis of the tomography and reflectometry data has been performed at MIT and University of Victoria. The WHOI group has focused on analysis of the acoustic communications, array shape tracking, and SPL data. The communications data consists of a sequence of packets broadcast at approximately 1 minute intervals from an AUV during a mission. QPSK modulation at 5000 bits-per-second was used and information about the AUV depth, position, and status were encoded in each packet. The signals were received on 8 hydrophone channels at the mooring closest to the vehicle. Despite the short ranges involved, the communications channel in Haro Strait is challenging on account of the high ambient noise level, due to boat traffic, and the extremely dense, widely spread, and time-varying multipath, resulting from the bowl-like bottom topography. Analysis of the communications data gave rise to several innovations in the autonomous receiver algorithm under development at WHOI, pertaining to Doppler correction and complexity reduction. These improvements were the subject of two international conference papers. Using the improved receiver algorithm, many of the Haro Strait communications packets have been decoded successfully. Moreover, the decoding process now produces information, such as the velocity over ground of the vehicle in the vehicle-array plane, of potential value in vehicle navigation. Figure 1 shows an example decoding result for a Haro Strait AUV communications packet for which error-free decoding was obtained.

The moorings deployed at Haro Strait used an innovative and potentially low-cost array tracking system to pin-point the hydrophone positions as required for tomographic inversion. Although tested successfully during dock trials at WHOI, this system did not meet performance expectations at Haro Strait due to the presence of strong echoes in the received tracking signals. Recognizing this, raw signals were recorded from the tracking system throughout the experiment, providing the opportunity to improve tracking accuracy by post-processing. Work is continuing both at WHOI and by the MIT group to determine reasons for the echo signals and to evaluate post-processing methods. A least-square-error curve-fitting technique is currently being examined at WHOI and initial results are promising.

The underwater sound level during the experiment period was of interest for two reasons. First, there was concern that the active acoustic components of the experiment (tracking, tomography, and communications signals) could lead to habitat avoidance on the part of the marine mammals in the immediate vicinity (in particular, resident Orca, Dall's and harbor porpoise). Secondly the ambient sound level effected the accuracy of the acoustic measurements. In response to the first concern, the experiment operated under a National Marine Fisheries Service (NMFS) permit requiring sound level monitoring and visual marine mammal census throughout the experiment. For these reasons, ambient sound measurements were made at each mooring throughout the experiment. The resulting data, processed as part of this years data analysis task, provide an

important picture of the magnitude of boat traffic noise nuisance in the Haro Strait area and were instrumental both in preparing the NMFS report and in determining the reliability of the tomography measurements. An example spectrum level result recorded at the north-west mooring on days 188 and 189 of 1996, is given in Figure 2.

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Equalizer Results Summary

7-Feb-97

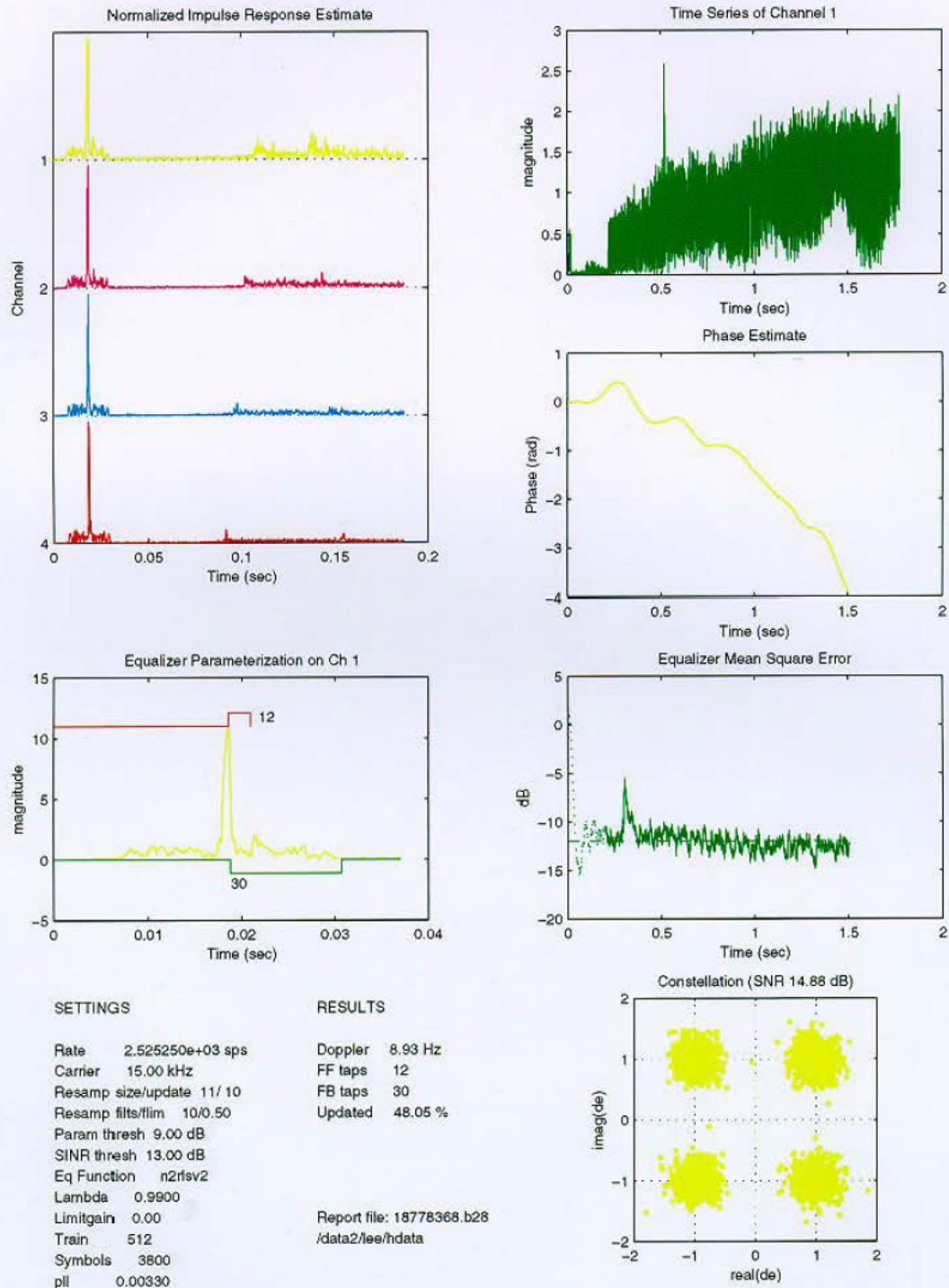


Figure 1: Haro Strait acoustic communications example result

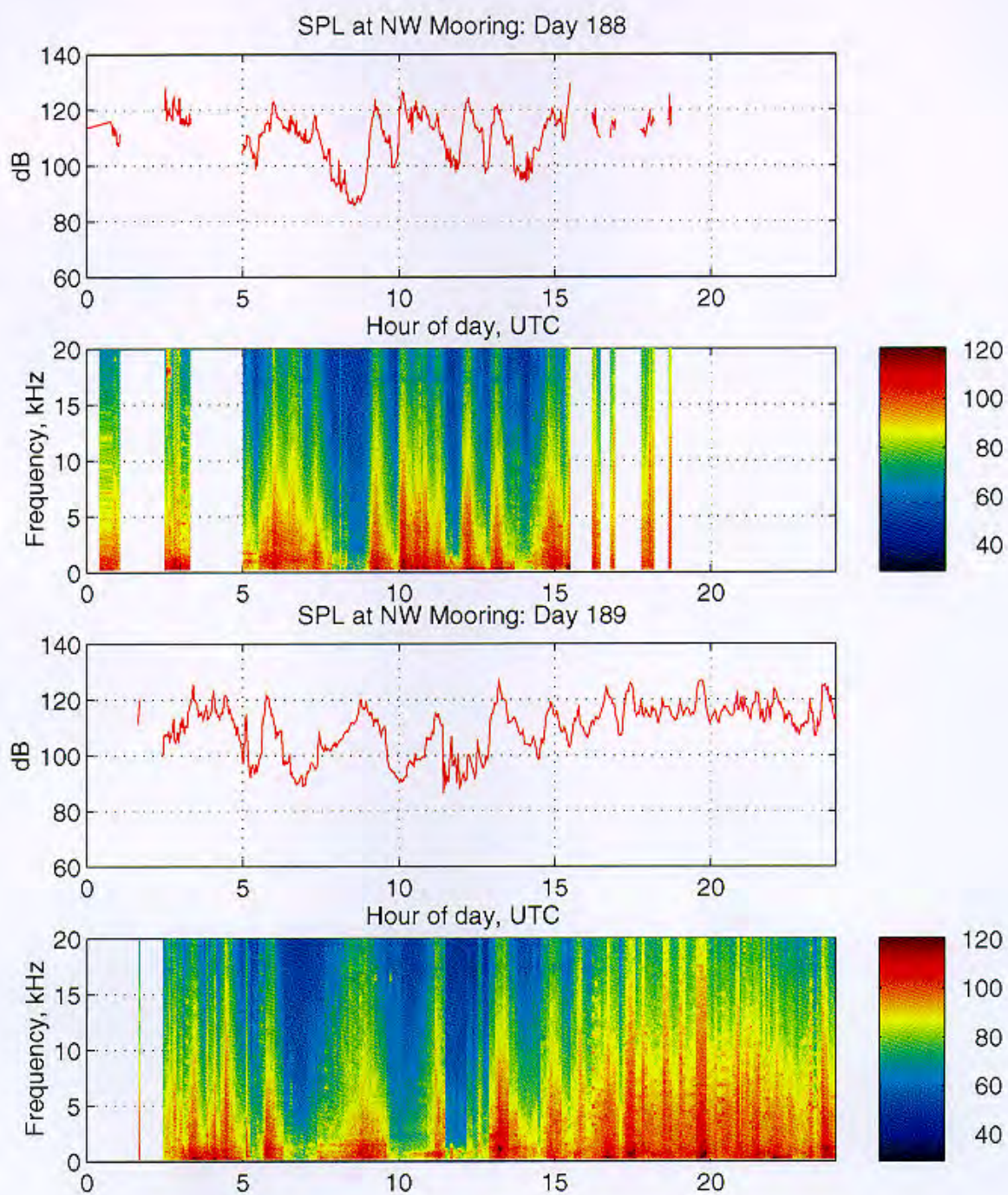


Figure 2: Example sound level result from Haro Strait